NATURAL SCIENCES IN THE HIGHER SCHOOLS OF GERMANY

I.

IN the early days of the German schools the classical languages and literatures formed substantially the entire curriculum. The Reformation induced some minor changes and gave a new impulse to educational activity, but we are told that in Sturm's school in Strassburg—the most famous and influential school of the sixteenth century—neither history, nor mathematics, nor the natural sciences, were considered of any consequence; that for thirty years even the elements of arithmetic were not taught, and that throughout Sturm's long tenure of office arithmetic and geometry, geography and astronomy, were never much in evidence except on paper.

The Jesuits did little more in science; *pietas et boni mores*, their great aim in education, seems to have been conceived of as independent of the physical world, but with the advent of the seventeenth century a new view of the world was promulgated and the necessity of man's knowing the significance of his environment became obvious. The ideas of Bacon and Locke were domiciled in Germany by the teachings of Ratke and Comenius, but it would be erroneous to suppose that the ideals of these advanced thinkers were speedily realized in the Fatherland. Not even in the *Ritterakademien* of the following century did the natural sciences have any important place; nevertheless, the secondary schools of the eighteenth century, influenced doubtless by A. H. Francke's experiments in Halle, recognized for the first time the utility of certain forms of scientific knowledge. Utilitarian considerations, pure and simple, determined the admission of *Heimatskunde* into the curriculum of the first *Real*-schools. As these institutions became more clearly differentiated from the humanistic schools the practical advantages of

the natural sciences were the more apparent, and in place of the desultory work in general science systematic study of particular sciences was introduced.

The natural sciences have been prescribed as an integral part of the curriculum of all Prussian secondary schools since 1816. The southern states did not recognize the innovation for several years, and when they did less time was given to the sciences than in Prussia. This distinction is still maintained in respect to the comparative time-allotment. The Prussian *Gymnasium* has eighteen week-hours in the sciences, an average of two hours a week for each class; Bavaria gives but five hours to natural history as compared with eight hours in Prussia, and does not yet recognize physics as a subject independent of mathematics; Württemberg prescribes a total of fourteen week-hours for natural history and physics, an average of one and four-tenths hours a week.

At the present time the biological sciences are everywhere completely separated from physics and chemistry. The course in natural history begins in *Sexta* with children of nine years of age, and is continued in the Prussian *Gymnasien* during the succeeding four years, in the *Realgymnasien* and *Oberrealschulen* for six years. Physics and chemistry are taught only in the upper classes.

The chief aim of all instruction in the natural sciences is to cultivate the habit of keen and accurate observation, to strengthen the pupil's reasoning powers, and to increase his ability of expressing clearly what he sees and thinks. The acquisition of a fund of systematic knowledge or useful information is a secondary consideration. Pedagogical writers and practical teachers are agreed in this; furthermore there is general unanimity of opinion touching the subject-matter and methods of instruction. So far as is possible the material used should be taken from the pupils' immediate environment; the order of progression should be from the near and simple to the more remote and difficult. In methods it is generally agreed to be advisable to work inductively rather than deductively. A revolution in methods of teaching is even now taking place.

A few years ago the ideal was to give a systematic presentation of each science; the subject-matter might come from near or far providing it satisfied the general scheme. The leaders in theory and practice of the present day have no hesitation in throwing over any scheme that early takes the child out of his local environment and substitutes for his own observation, crude though it may be, the ready-made reflections of the textbook or the opinions of the teacher. As between a little of all that can be known and all that can be known of a little, there can be no doubt in the German mind; to drink deep or not at all is surely a German characteristic. Nevertheless it is impossible to follow out all lines that have their origin in the home environment; a selection must be made, and the government allows absolute freedom of choice to schools and teachers as to what shall be taught within the limits above mentioned. Success or failure, therefore, in science work reflects directly upon the teachers and the management of schools.

The first steps in natural history lead the child to observe the simplest and most familiar forms of plant and animal life in his home region. The wisdom of the teacher is manifested in the selections he makes for class instruction; not all groups are represented in the local flora and fauna, and consideration of too many representatives from any one group is precluded for lack of time. Training in observation demands that the pupil handle the specimens studied and report his own opinions. In botany this can be easily managed, but in zoölogy it becomes a different problem. No laboratories are provided for individual work in natural history, and consequently from the very beginning the opportunity for individual observation is greatly restricted. To overcome this obstacle magnificent collections illustrating almost every department of natural science have been gathered by many of the leading schools. In botany most schools will have a complete herbarium of domestic plants and many specimens of foreign flora. Besides this, models are commonly used for class demonstration, and excellent charts of foreign plants supplement the illustrations of text-books.

Mounted animals, skeletons, and preparations in alcohol are found in large numbers in some schools and are put to good use in the class room, but without laboratory work there is small chance of promoting those habits of "keen and accurate observation" everywhere demanded of instruction in science. Again, the teacher must rely largely on models and charts. And although the German teacher is fortunate in having his choice of the best models and charts in the world, yet there is an obvious contradiction between the demands of theory and the results of practice. In other respects, too, practice often lags so far behind theory that one is inclined to doubt the all-sufficiency of high ideals even in Germany.

It is with no little hesitancy that I attempt an explication of the prevailing methods of teaching the natural sciences in the German schools. So much of the instruction to which I listened was unpardonably bad, that I much distrust my ability to present clearly that which is obviously commendable. Fortunately my experiences were not always disappointing, and on the whole it may be quite as well for the reader to know that German schools and German teachers are not always the paragons of excellence that some would have us think.

We have seen that more time is given to the sciences in the *Real*-schools than in the *Gymnasien*—in Prussia a total of thirty week-hours in the *Realgymnasien* and thirty-six in the *Oberrealschulen*, as compared with eighteen in the *Gymnasien*. Furthermore the science work in the *Real*-schools is taken more seriously than in the *Gymnasien*. In consequence I have selected as a type of what is done in Prussia the course of study prescribed in the *Königstädtisches Realgymnasium* of Berlin. This is one of the oldest *Real*-schools of the city, founded in 1832, and now attended by nearly six hundred students. For the fifteen classes there are twenty *Oberlehrer* and six *Hilfslehrer*, besides four teachers of drawing, music, and gymnastics. Three *Hilfslehrer* and six *Oberlehrer* teach natural science—no one, however, devoting himself exclusively to science work. The most frequent combinations are natural history, geography, and arith-

metic; natural history, geography, and German; physics (or chemistry), algebra, and geometry; chemistry, natural history, and arithmetic. The *Director* teaches physics, natural history, and religion.

The course followed in this school comes near the high-water mark in Prussia. Such differences as exist in other schools are chiefly due, as I have shown, to the preferences of individual teachers. The teacher who delights in field work will arrange for class excursions, not merely for the sake of securing botanical specimens, but with a view of interesting his pupils in nature and nature study. Another teacher may have a genius for class-room demonstration, and succeed thereby in arousing the right form of scientific curiosity. A third may know how to utilize the laboratory and make it an efficient instrument in promoting inductive research. The *Königstädtisches Gymnasium* has such teachers, and we find represented here all phases of scientific work to be found in any secondary school.

The course in natural history as outlined in the programme of 1895–6 is as follows:

SEXTA, 2 hours. Summer: Description of various plants with large and simple flowers. Explanation of morphological principles. Winter: Description of various mammals and birds and their habits. Explanation of the most important zoölogical principles and laws. —— Text-book, Vogel, Müllenhoff, Kenitz-Gerloff, *Botanik und Zoölogie, Teil I.*

QUINTA, 2 hours. Summer: Comparative description of plants of simple structure with a view to their classification according to common and differential characteristics. Study of morphological principles continued. Winter: Comparative description of mammals and birds with special attention to scientific classification. The skeleton of man, of other mammals, and of birds. —— Text-book, same as in *Sexta.*

QUARTA, 2 hours. Summer: Comparative description of related plants and species, with special attention to various representatives of families of highly developed plants (*Umbelliferæ* and *Compositæ*). Extension and classification of the principles of morphology. Toward the end of the semester practice in plant analysis according to the Linnean system. Winter: Comparative study of mammals and birds continued. Description of various representatives of reptiles, amphibians and fishes. Principles of the skeleton

of vertebrates. Classification of vertebrates. —— Text-book, same as in *Quinta.*

UNTERTERTIA, 2 hours. Summer: Comparative study of compound flowering plants, *e. g.*, *Amentaceæ* and *Germinaceæ.* Characteristics of the most important families of uncultivated plants. Study of plant morphology continued. Study of plant growth. Analysis of plants. Winter: Comparative study of the anatomy and growth of articulates. Characteristics of insect species. Review of the system of vertebrates. —— Text-book, same as in *Quarta, Teil II.*

OBERTERTIA, 2 hours. Summer: Study of gymnosperms and cryptogams, and the most important of cultivated foreign plants. Explanation of the chief morphological, biological, and anatomical characteristics of the same. Arrangement according to the natural system of all plants thus far studied. The simplest principles of plant distribution. Practice in plant analysis. Winter: Description of certain representatives of the lower animals. Review of all animals thus far studied, according to types and classes of the natural system. Fundamental principles of palæontology. —— Text-book, same as in *Untertertia.*

UNTERSECUNDA, 2 hours. First semester: The anatomy and physiology of plants and animals continued and extended. Anthropology. Second semester: Physical and chemical peculiarities of water, air, fire, and earth. —— Text-book, same as in *Obertertia, Teil III.*

The instructions of the Prussian Department of Education emphasize observation and description of natural objects. The importance of accurate description is seen in the terms everywhere used in Prussia designating the first division of science work, *Naturbeschreibung;* the older designation, *Naturgeschichte,* is still used in Hamburg and some of the southern states.

A necessary prerequisite to observation and description is that the child shall have something to observe and describe. Specimens of plants may be put in the pupil's hand for this purpose and the entire work restricted to the class room. Such a plan may give practice in description, but intelligent observation of nature can be taught only by going to nature herself. The structure of plants and animals may be learned in the class room and laboratory, but the significance of plant and animal life, the interdependence of the lower and higher orders, and the influence of climate, soil, and moisture upon all forms of life are to

be seen only out-of-doors. For this purpose class excursions are usually arranged on half-holidays. The *Königstädtisches Gymnasium* arranges for one excursion a week. Pupils of any class in natural history may take part, but participation is optional. The success of the undertaking is entirely dependent upon the teacher. As may be imagined some teachers have more followers than they can readily manage ; others, after making a few trials, conclude that field work is a farce.

These excursions are generally of a half-day's duration, but in some schools there is a midsummer outing of a week or two. The pupils visit various places of interest pertaining to some particular study or line of work which they are about to begin. Geographical points are located and historical events impressed upon the children's minds by perceiving the actual places of their occurrence. Botany, zoölogy, geography, geology, and mineralogy are thus studied objectively, and much material is collected for use in the class room. The appearances and habits of various birds and animals are discovered by experience; the life and habitat of many plants are made known; and all this scientifically conducted and explained by the teacher, serves not only to increase the knowledge but also the interest of the pupil in the pursuit of his studies. The main object, that of increasing the power of observation, is certainly accomplished. It is a difficult matter in the large cities to arrange for excursions far enough into the country to see nature at her best, but parks and zoölogical gardens offer a fair substitute. It must be said, however, that a trip through a city park does not furnish much material for class use. To offset this difficulty many city schools have adopted the charming expedient of maintaining flower gardens of their own. The children plant the seeds and tend their growth, labeling each specimen in true botanical fashion. I have observed, too, that in some of the smaller towns the schools have not only beautiful gardens of flowering plants, but miniature parks, set out with trees and shrubs of rare beauty. A more effective means of awakening an interest in botany, I think, would be hard to devise. Here is a suggestion of what

might be done with the spacious grounds of our American public schools.

I have already spoken of the part played in instruction by the school museum. Considered as a means of elucidating obscure problems incident to class teaching, these collections are very valuable. In this respect some secondary schools rival the smaller universities. The danger is that so long as somewhere in the school there is a chart, model, or mounted specimen of each object studied in class, the museum will be drawn upon for its stores to the neglect of almost all field-work. Precisely this state of affairs exists in the majority of schools that I have visited. My own experience would lead me to say that the average teacher relies almost exclusively upon accumulated stores of past years. While in theory each pupil is expected to have in his hands a specimen of all the commòn plants as they are discussed in class, I have seen the pea studied by a class of thirty boys from a model that never left the teacher's desk during the hour; and at the close of the lesson not a word was said about noting the plant in its cultivated state, although acres of it were growing within a mile of the site, but, on the contrary, the home task as assigned was *to copy the drawing given in the text-book*. I still have my doubts whether the majority of the class did not conceive of the true flower as being about a foot in diameter.

Such an instance as the one just related is of course an extreme case. The teacher, if he had any object other than drawing his salary, was aiming at systematic botany. And, notwithstanding the efforts of recent years, many of the science teachers are still engaged in teaching botany and zoölogy, physics and chemistry. There is plenty of evidence of this in almost every school. Even the course of study outlined above seems to emphasize at every turn the systematic presentation of the subjects.' In the last resort we must turn to the methods employed in instruction rather than the material of the course in order to evaluate correctly the work in natural history.

Observation, inference, and description go hand in hand.

Assuming that a class is provided with something to examine, it is the teacher's business to see that right observations are made. Nothing is gained by puzzling the child or allowing him to waste time and energy in a fruitless search for something he might find instantly if properly guided. As if anyone ever learned to see by groping in the dark! This conception of teaching is characteristically German. One of its principal advantages is that it permits the teacher to lead his pupils quickly and easily to an understanding of some general principle which might otherwise be misinterpreted or overlooked entirely. The course of study, therefore, outlines the general principles which are to be arrived at; the teacher alone is responsible for the methods of procedure.

I find among my notes a fairly typical lesson in zoölogy with boys of ten years of age (*Quinta*). The school is a private institution in central Germany; the topic, "the Seal." The lesson opened with a review of the families of animals already studied, a few individuals being cited as characteristics of each group. Next followed a brief summary of the previous lesson on the means of identifying animals by the teeth and skull. Specimens of these parts were distributed among the class and each boy was requested to name the animal to which his specimen belonged and state the grounds on which he based his inference. Great interest was manifested in this part of the work which was continued for about twenty minutes.

The teacher next directed their attention to a finely mounted seal standing upon his desk. His questions ran somewhat as follows: "What is it? Who has seen one? Where? What did it do? How long can it stay under water? What does it do when it comes again to the surface? How is it able to stay so long under water? Why does it go under water? What does it get there? What else will it eat? Will it eat fresh-water fish? (Several boys are called up to examine its nose and feet.) What about his legs — number, shape, fingers, etc.? How can it close its nostrils? What can you say of its coat? How does the fur lie? What advantage is it to the animal? How

long are its whiskers? What are they for? How long is this seal? (Boy measures it and reports to class.) How broad? What is the shape of its body? Why does it not freeze in the ice-cold water? Is the body of the living seal of the same temperature as the water? What is the temperature of this room? What is the temperature of your body? What enables the seal to keep so warm amid such cold surroundings?"

From the trend of these questions it is easy to infer the answers given by the class. In regard to the habits and habitat of the seal the teacher had to supplement the knowledge of the class. The main purpose of the lesson, apparently, was to emphasize the difference in temperature between the animal body and its surroundings. The subject of food assimilation and oxidation of tissue was treated at length. The recitation, measured both by the interest manifested by the pupils and the skill with which the teacher brought the lesson home to them, was a decided success.

An essential part of the descriptive work in science is the making of a detail-drawing of every object studied in class. In general this is the only home task in science work. The care exercised in writing up the notebooks and in making the drawings is everywhere apparent; sometimes, I suspect, teachers of doubtful ability cover up their own sins by fine displays of notebooks on all public occasions. But whatever the motive may be, it is certainly true that drawing is of most effective service in all science teaching.

Laboratory work, as has been said, is practically unknown in natural history. The nearest approach to it is in plant analysis, but the methods employed preclude the possibility of independent work. The process is precisely the same as is followed in the solution of mathematical problems.[1] Pupils are not given a number of specimens and told to work them out previous to the next lesson. Having learned inductively the main principles of the Linnean system from the classification of individuals studied,

[1] See SCHOOL REVIEW, October-November 1894, on the Teaching of Mathematics in the Higher Schools of Germany.

this knowledge is applied in the process of identifying new specimens. The teacher asks for each of the essential characteristics. The responses of the class are based on strict observation of the specimen in hand. At each step the teacher reviews past observations and calls up the peculiarities of the various classes, orders, and families. Under such leadership it would be strange if any pupil should fail in identifying his specimen. Notwithstanding the great stress put upon observation and description in natural history one is forced to the conclusion that there is little independent observation or unbiased description.

There is something to be said for the teacher who is unable to make his work popular and successful. The residuum of many conversations with science teachers and others is to this effect: In the first place the universities, where all secondary teachers must get their training, take no heed whatsoever to the needs of the schools. The sciences are taught in the most thorough and intensive manner possible. In other words, the man who, after five years of advanced study in the university, the greater part of the time devoted to independent research, can adapt himself to the needs of nine-year-old children is a genius. It is too much to expect of the average man till the university offers training courses for teachers. In the second place the government, while apparently expecting field-work from the fact that botany is regularly put in the summer semester, makes absolutely no provision for it and allows no credit for what may be done. It means, too, that teachers and pupils must give up their half-holidays to outside work. Furthermore the government makes no allowance for the extra demands made upon the science teacher in the collection and preservation of material, the preparation of objects for demonstration, and the supervision of the laboratory work; he must put in full time—twenty to twenty-four hours a week—the same as his colleagues. And finally the excuse is often urged that in the *Gymnasien* the pupils feel it is of small consequence whether they are proficient in the sciences or not; there is no final examination, and even the indolent and dullards

will be promoted if only they know some Latin, Greek, and German. The science teacher, especially if he be not cast in the classical mold, sometimes is made to feel that his social and professional standing is questionable.

Such statements, though coming from thoughtful teachers, should not be regarded as the whole truth. It is unquestionably true that in some schools the teachers of science belong to a different social stratum from the other teachers; but the accident of birth is the important factor. A gentleman may teach science and not lose caste. Germany is far from being a pure democracy, and social distinctions are not always obliterated by recognition of personal worth. On the other hand, there is just cause for complaint from gymnasial teachers when proficiency in other subjects will secure a pupil's promotion in science. This is a serious problem and so long as the government leaves it unsolved there can be no doubt that science is really considered a second or third-rate study.

But after all the shortcomings in the teaching of natural history in the German schools are discovered we are obliged to express high regard for what is accomplished by the leaders of the new movement. As a conspicuous instance of the acme of arrangement and method I subjoin an outline of the course in nature study followed during the first two years in the Jena *Gymnasium*. It will be noted that the aim is not only to give the child information about nature, but to help him to see scientific facts in their interrelations. For this purpose nature study is closely correlated with *Heimatskunde*, that branch of study which aims to give the child an elementary knowledge of his home environment, physical and social. Side by side with the study of botany and zoölogy goes that of geography, history, and the legendary tradition of the country. Few schools in Germany show such careful attention to details, and have so successfully worked out the correlations with kindred subjects.

Nature study in *Sexta*:[1] 1. The local environment;—(*a*) surface elevations; hills and valleys of the neighborhood. (*b*)

[1] See Programme of the Jena *Gymnasium*, 1891.

Water courses and roads: formation of valleys. Neighboring water sheds. Influence of the water courses on the local industries: grist mills on the smaller streams; city woolen mills on the Saale. Land, road, and water ways: paths, roads, highways, railroads, boating, rafting. (*c*) Climate of mountains and valleys. Influence of mountain and forest on atmosphere. Vegetation of mountain sides influenced by position, exposure, etc. (*d*) Plants and animals: grasses cultivated for fodder (clover, lucerne, etc.), grains (wheat, rye, oats, barley, etc.), esculent plants, plants valuable for manufacturing purposes (flax, hops, etc.), garden fruits, and wild flowers (violet, rose, bell-flower, sunflower, crane's bill, etc.). Plant life, distribution, habitat, dependence on soil, climate, and animals—these facts to be pointed out and studied on the class excursions. The animals studied are as follows: bat, porcupine, mole, shrew-mouse, field-mouse, weasel, squirrel, swine, deer, horse, duck, goose, eagle, woodpecker, song bird, common adder, lizard, frog, carp, honey-bee, May beetle, and ant. Interdependence of animals and man.

In *Quinta* the work is extended beyond the local environment, but is conducted upon the same general principles. While the geography of Thuringia is being studied the names and location of the mountains, towns, valleys, and river courses are learned. In the lessons devoted exclusively to nature study the influences of these natural phenomena upon the climate and industrial life of the people are emphasized. Special industries and natural resources of certain towns, as glass-blowing, the making of pottery, mining of iron and coal, hot springs, etc., are carefully explained, and, when possible, excursions are made to the more accessible towns. The products of the land, its flora and fauna, are studied in so far as it is a continuation of the work in *Sexta*. In a country so diversified as central Germany it is possible to find types of the most common plants and animals within a radius of fifty or a hundred miles. The extensive mountain forests with their well-stocked parks (game animals) and fertile valleys afford abundant opportunity for elementary

study of forestry and the more important agricultural industries.

The excellent results obtained in the Jena *Gymnasium* in some classes and in some schools in all classes lead me to infer that when the sciences are poorly taught the causes are not far to seek. "Where there's a will there's a way" is certainly true in respect of this subject as of all others. The reason why most schools have no "way" worth following is because there is no "will" worth consideration. This is conspicuously true in the case of physics and chemistry in all *Gymnasien*, and with botany and zoölogy in not a few.

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